THE PHYTOTOXIC POTENTIAL OF BRACKEN, PTERIDIUM AQUILINUM (L.) KUHN

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Bracken, *Pteridium aquilinum* (L.) Kuhn, has an almost worldwide distribution that extends from the edges of the polar regions to the heart of the tropics. It grows under environmental conditions ranging from tropical through Mediterranean to boreal. There are many references in the literature to the dominating influence of bracken over many types of vegetation in these different situations (Isaac, 1940; Das, 1947; Schelpe, 1951; Winne, 1952; Watt, 1955). It is commonly referred to as a very troublesome weed, with much effort and expense put into its eradication (Fenton, 1936; Braid, 1948; Gilkey, 1957). All of the ecological studies of bracken under these varying conditions name forms of competition (for water, light, or nutrients) as the probable mechanisms that this fern brings to bear upon associated plants. But work now in progress on bracken suggests that the release of phytotoxins from the fern fronds often may be the limiting factor rather than competition.

This study involves areas in the Santa Ynez Mountains near Santa Barbara, California. Meadows that occur as large openings in an oak woodland often are dominated by bracken, this occurring almost to the complete exclusion of herbaceous grasses and dicots and even many woody plants. Portions of the meadow not dominated by bracken are vegetated predominantly by weedy annual grasses such as *Bromus rigidus* and *Avena fatua* and an array of annual dicots. All of the various forms of interference of which bracken might be capable are being examined in order to explain the mechanisms of the fern's dominance over associated species. Laboratory evidence thus far accumulated suggests that allelopathy is one of the most important mechanisms.

Detection of phytotoxicity. In a search for the presence of toxins, both dead and live bracken fronds were collected from meadows in the area of San Marcos Pass in the Santa Ynez Mountains. Water extracts were made by soaking 65 grams of intact fronds in 1500 ml of double distilled water for two hours. The extract was filtered and a portion was then concentrated in a Buchler flash-evaporator at 49°C to four times the original concentration. Both concentrations were subjected to a bioassay for toxicity. Seeds of *Bromus rigidus* were soaked for two hours in the solution in which they were to be tested. Ten seeds were placed on 5×5 cm cellulose sponges, 3 mm thick, over which had been placed a 5×5 cm square of Whatman #3 chromatogram paper. Each sponge had been soaked in the test solution (the controls in double distilled water) and then placed in petri dishes sealed with parafilm. The dishes were placed in a growth chamber and incubated in darkness for 48 hours at 26°C.

TABLE 1. RADICLE GROWTH (MM) OF BROMUS RIGIDUS IN WATER EXTRACTS OF BRACKEN FRONDS. (N = 30 FOR ALL MEANS, NUMBERS IN PARENTHESES ARE PERCENT OF CONTROL.)

Test	Control	X	4X
Green fronds	25.6 (100)	25.3 (98.5)	——
Yellow fronds	22.3 (100)	22.6 (101.0)	18.3 (81.7)*
Dead fronds collected before rains:			
1967	21.8 (100)	18.6 (85.4)*	8.3 (38.1)**
1968	15.4 (100)	13.1 (85.0)*	5.3 (34.4)**
1969	23.1 (100)	17.6 (76.2)*	5.0 (21.6)**
Dead fronds collected after one rainy season	22.1 (100)	18.1 (82.0)*	15.5 (70.0)*
Dead fronds collected after 2–3 rainy seasons	20.1 (100)	19.9 (99.0)	19.9 (99.0)

*Significant at 5% level.
**Significant at 1% level.

Results of several tests are listed in Table 1. Extracts of green fronds proved to be insignificantly toxic, even the extract concentrated 4 times. Yellow fronds beginning to show signs of senescence exhibited moderate toxicity in the concentrated extract (81.7% of control). Completely dead fronds were collected, over a series of several growing seasons, before any leaching by rainfall had occurred. Water extracts of these fronds proved to be highly toxic even when unconcentrated. As the fronds are exposed to the leaching effects of rainfall, toxicity is rapidly removed. After one winter season, toxicity is severely reduced even in the concentrated extract, and after two or three seasons, the toxic principle appears to be completely removed. Thus it is apparent that when the fronds age and die, toxins are readily leachable, even by such a simple method as soaking in water. Exposed to a series of leaching rains, the toxins are released from the fronds into the surrounding environment.

To test the idea that the toxic effect of bracken can be transferred to other plants by way of the soil medium, water extracts of whole fronds were used to water seeds planted in soil. A sandy-loam soil was collected from the grassland adjacent to the bracken stand at the study site. This soil was air dried, passed through a 2 mm screen (U.S. Standard Soil Sieve #10), and 50 grams then placed in each of 24 covered storage dishes (500 ml size). *Bromus rigidus* or *Avena fatua* were planted in the soil, 20 seeds to a dish, watered with 13 ml of extract, sealed with parafilm, and incubated at 26°C in the dark. *Bromus* was incubated for 48 hours and *Avena* for 72 hours. Six dishes were watered with double distilled water as controls. Upon measurement of radicle lengths, it was found that *Bromus rigidus* was inhibited significantly only by the extract concentrated four times (39.0% of control). *Avena fatua* was inhibited by the unconcentrated extract to 75.1% of control, while the concentrated extract inhibited the growth of the radicle to 37.7% of control. Although germination was practically 100% for the tests involving *Bromus rigidus,* the germination of *Avena fatua* was reduced in the concentrated solution to 76% of control. Thus toxicity is evident even in the soil medium, suggesting that one of the important means of transfer of the inhibitors to other plants in the environment is through leachates from bracken fronds washed into the soil by rain, fog, or dew drip.

Since the principal mechanism of transfer of toxins from the fronds to the environment most likely is in some form of precipitation, an artificial means of collecting rain drip was devised in the laboratory. A four-foot square frame was constructed of wood, and light twine was strung between the sides at 2–3 inch intervals to form a grid into which fronds could be inserted at the same density and in the same upright position observed in the field. The complete grid was then suspended over a funnel constructed from a four-foot square sheet of plastic. Distilled water equivalent to a quarter inch of rain was applied to the grid at intervals over a two-hour period in the form of a fine mist. After the drip was collected, it was filtered, concentrated, and bioassayed by the previously described sponge method. The leaching was repeated five times, with the fronds fully dried between leachings, the entire series being completed in five days. The bioassay results are given in Table 2. The initial leaching

TABLE 2. RADICLE GROWTH (MM) OF BROMUS RIGIDUS IN ARTIFICIAL RAIN DRIP FROM BRACKEN FRONDS. (N = 30 FOR ALL MEANS; NUMBERS IN PARENTHESES ARE PERCENT OF CONTROL.)

Test (Wash #)	Control	X	4X
1	19.6 (100)	15.1 (77.0)*	2.7 (13.8)**
2	20.5 (100)	18.4 (89.7)	10.7 (52.1)**
3	21.2 (100)	19.6 (92.0)	15.5 (73.0)*
4	20.7 (100)	15.0 (72.0)*	12.5 (60.0)**
5	20.8 (100)	16.5 (79.3)*	13.4 (64.4)**

*Significant at 5% level.
**Significant at 1% level.

proved to be quite toxic at both concentrations. The subsequent leaching gradually lost toxicity, but as can be seen in the results of the fifth wash, considerable toxicity is still readily leachable. Thus the inhibitory effect of the first rain would be the most significant, but the following rains could act as a reinforcement.

Greenhouse experiment. An experiment was devised to test for the release of toxins from bracken and their subsequent interference with the growth of other plants. Dead frond material was broken by hand into small pieces, while other fronds were ground in a Thomas Company Wiley Mill using a 20-mesh grid. Grassland soil was again used, with 560 grams placed in each of several small plastic pots. Six grams of broken fronds or ground fronds were added to separate pots and mixed well with the soil, there being four pots in each treatment. Six grams of sterile pumice rock were added to soil in four other pots as a control. Ten *Avena fatua* seeds were planted in each pot and watered daily with distilled water. Growth of the shoots was measured at 2–3 day intervals (fig. 1)

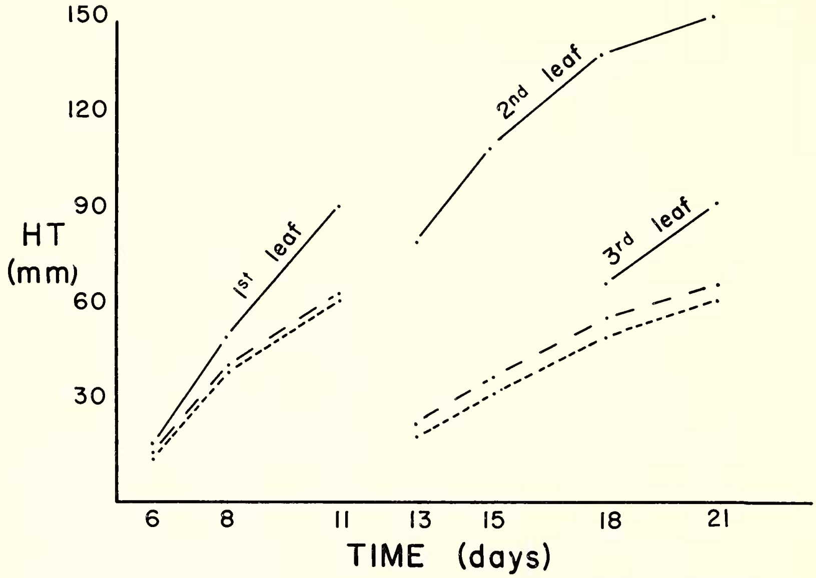

FIG. 1. Height of shoots (mm) of *Avena fatua* grown in pots and measured at intervals. Each point is the mean of 40 plants under a specific treatment: solid line, control; broken line, broken fronds in soil; dotted line, ground fronds in soil. The third leaf was initiated only in the controls.

and after three weeks, roots and shoots were harvested. Dry weights were determined after 24 hours in a drying oven at 70°C. Mean shoot and root weights for the pots containing broken or ground frond material were almost identical, with the roots averaging 0.029 grams per plant and the shoots averaging 0.009 grams per plant. In the controls containing sterile pumice rock the roots averaged 0.036 grams per plant and the shoots averaged 0.019 grams per plant. The reduced yield of both roots and shoots, coupled with the very pronounced inhibition of plant height, demonstrate well the toxic effect of bracken fronds. It is significant that the broken fronds are approximately as toxic as the finely ground fronds, indicating the ease of leaching of the toxic compounds even without so drastic a measure as grinding.

Identification of toxins. Work is still in the initial stages towards the isolation and identification of the toxic compounds involved in the interaction. Because the toxic principle is transported in some form of precipitation, work is being restricted to the water soluble compounds, predominantly the phenolic acids. Cinnamic acid has been tentatively identified.

Reference has been made in the literature to the possible presence of various other cinnamic acid or benzoic acid derivatives in bracken fronds (Bohm and Tryon, 1967), but these have not been isolated thus far.

Discussion. The presence of highly toxic compounds in bracken fern has some very important implications concerning the probably widespread occurrence of allelopathy. It is a common belief that the release of phytotoxins by a plant and their subsequent role as a factor of interference between plants is a geographically restricted phenomenon. Since ecologically effective allelopathy has been worked out in detail in only a few cases (Muller, 1969) under rather localized conditions, many researchers still feel that the other more conventional forms of interference are the only significant interactions determining vegetational composition over most of the world.

Bracken dominates, or even excludes, associated plant species in a broad spectrum of habitats within its wide geographic range. In our numerous field observations, extending over 40° of north latitude and from semi-arid to humid climates, we have been impressed by the similarity of patterns exhibited. Suppression of other species by bracken is not completely density-related. Even open stands of bracken in which ample light reaches the soil surface are characterized by extraordinary reductions in the growth of other species. Thus, in Costa Rica, California, Oregon, Washington, and Montana, in climates ranging from hot to cold and from wet to dry, there occur suppressions of plant growth which cannot be related to light competition, soil moisture, or other forms of physical interference. The toxicity of bracken demonstrated by our laboratory experiments strongly suggests the hypothesis that allelopathy is the mechanism whereby this plant induces the pattern so extensively exhibited. The widely held view that toxic compounds are rapidly removed from the habitat by heavy leaching of the soil is challenged by this proposal. We are currently extending our field experimentation into humid climates with the purpose of testing the hypothesis that phytotoxins of bracken are ecologically effective in areas of high rainfall.

Literature Cited

Bohm, B. A. and R. M. Tryon. 1967. Phenolic compounds in ferns. I. A survey of some ferns for cinnamic acid and benzoic acid derivatives. Canad. J. Bot. 45:585–594.

Braid, K. W. 1948. Bracken control—artificial and natural. Jour. Brit. Grassland Soc. 3:181–189.

Das, Pritam. 1947. Panvin burning in some upper Simla Hill states. Ind. Forester 73:121–122.

Fenton, E. Wyllie. 1936. The spread of bracken (*Pteris aquilina* L.) in Scotland and its ecological significance. Agric. Prog. London 8:66–72.

Gilkey, Helen M. 1957. Weeds of the Pacific Northwest. Corvallis, Ore. State College. 441 p. (cf. p. 14–15).

Isaac, Leo A. 1940. Vegetative succession following logging in the douglas fir region with special reference to fire. J. Forestry 38:716–721.

MULLER, C. H. 1969. Allelopathy as a factor in vegetational process. Vegetatio 18:348–357.

SCHELPE, E. A. C. L. E. 1951. The pteridophyta of Mount Kenya. Amer. Fern J. 41:65–75.

WATT, A. S. 1955. Bracken versus heather, a study in plant sociology. J. Ecol. 43:490–506.

WINNE, W. T. 1952. Pteridophytes from two Liberian counties. Amer. Fern J. 42:7–13.

NOTES AND NEWS

TWO NEW SPECIES OF TRAGOPOGON FOR ARIZONA.—*Tragopogon mirus and Tragopogon miscellus* (Compositae) were first described by Dr. Marion Ownbey from southeastern Washington. Both species are amphidiploids, $n = 12$, resulting from the following hybridizations: *T. mirus (T. dubius* Scop., $n = 6 \times$ *T. porrifolius* L., $n = 6$) and *T. miscellus (T. dubius* Scop., $n = 6 \times$ *T. pratensis* L., $n = 6$) (M. Ownbey, Amer. Journ. Bot. 37:487–499. 1950). The amphidiploid plants are easily distinguished from the diploid parents in the field by their robust nature, expressed particularly in the size of the mature achenes. The tetraploids were previously known only from eastern Washington and areas of Idaho. Recent collections of *T. mirus (442)* and *T. miscellus (479)* were made by Schaack in 1970, near Flagstaff, Coconino County, Arizona (DHA; WS). Examination and counts of chromosomes were made from pollen mother cells using the aceto-carmine squash technique. Specimens of *T. mirus* have been verified by Dr. Marion Ownby, while *T. miscellus* was given tentative identification. *Tragopogon mirus* is well represented in the Flagstaff area; its numbers often exceed those of the parent species in many populations. *Tragopogon miscellus* is known from only two plants in the Flagstaff area. Three species *(T. dubius, T. pratensis,* and *T. porrifolius)* were previously known for Arizona. The addition of two tetraploid species complicates the identification of the Arizona *Tragopogon* using available regional floras. A key contributed by Ownbey (C. L. Hitchcock et al., Vasc. Pl. N.W. 5:327–330. 1955) should be useful in identification of the Arizona specimens. Is is our belief that the occurrence of *T. mirus* and *T. miscellus* in northern Arizona represents an independent origin rather than an extension in range. Thanks are extended to Dr. Marion Ownbey for verification of our specimens and for valuable information.—
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